The mask, the aerosol, and the pandemic: The good, the bad, and the ugly

Dear Editor:

As of mid-June 2020, the COVID-19 pandemic has badly impacted lives and economy all over the world. More than 4,28,000 people have died with over 7.69 million people confirmed infected world over; countries are almost locked down with huge financial loses; universities and schools are closed with uncertainty all over; not only countries but states and districts have effectively closed their borders; and millions of people are confined to their homes. More than 5 months have passed since the start of the pandemic with virologists, infection specialists, and epidemiologists working hard to understand COVID-19 and how best to treat it. Among the many unknown facts, one thing is notably clear: COVID-19 is deadly and highly transmissible.

It is now much agreed upon by the infectious disease community about the modes of respiratory virus transmission between humans: Direct or indirect "contact" and airborne and therefore "aerosol transmissible."[1]

Aerosols: Size does matter

Aerosols or more appropriately bioaerosols are defined as a collection of particles suspended on a column of air derived from or incorporating material of biological origin. These bioaerosols can thus affect human health due to the presence of pathogens or allergens.[2] Typical size of aerosols ranges from 0.5 to 5 μm for smaller-sized particles (often referred to as inhalable particles); however, larger-sized particles can be associated with sizes up to 30 μm.[1,2]

Aerosols are so small that buoyant forces overcome gravity, allowing them to stay suspended in the air for long periods, or they evaporate before they hit the floor, leaving the solid particulate ("droplet nuclei") free to float very long distances, causing what we often refer to as "airborne" transmission.[1,3,4]

It is generally accepted that: i) small particles of 5–10 μm aerodynamic diameter that follow airflow streamlines are capable of short and long range transmission; particles of <5 μm readily penetrate the airways all the way down to the alveolar space, and particles of <10 μm readily penetrate below the glottis.[5] Large droplets of diameters >20 μm refer to those that follow a more ballistic trajectory (i.e., falling mostly under the influence of gravity).[1]

Aerosol would also include "droplet nuclei" which are small particles with an aerodynamic diameter of 10 μm or less, typically produced through the process of rapid desiccation of exhaled respiratory droplets.[1,6,7]

Droplets that are below 5 μm are considered the primary source of transmission in a respiratory infection,[8-10] and droplets that are smaller than 1 μm tend to stay in the environment as aerosols for longer durations of up to 8 h.[11] Aerosol droplets containing the SARS-CoV-2 virus have been shown to remain suspended in air for ~3 h.[8,12]

This is of importance in view of the ongoing pandemic because even though there is limited research on modes of spread, the results of available studies are consistent with "aerosolization of virus from normal breathing."[13,14]

We are not sure if every droplet contains virus, and even if it does, whether is it enough to effectively transmit disease, and to add to the enigma, the viral load necessary to cause infection is not known. Reports say that the virus load in the respiratory tract of an asymptomatic patient is similar to that of a symptomatic patient and this is of concern not only for us as health care providers but general population as well.[14]

Although the exact size of droplets produced is still debated, most sources agree that speaking, coughing, and sneezing produce droplets that are sufficiently small to remain airborne.[15,16]

The fate of these droplets largely depends on environmental factors such as humidity, temperature, turbulence, and thermal convection including meteorology, vehicle/human activity, and ventilation. In general, the larger droplets settle due to gravity and do not travel distances more than 1 − 2 m.[11] Other than environmental factors, it is the size and velocity of these particles which are important from a disease point of view. A 1000 μm droplet will fall 1 m in 0.3 s. A 100 μm droplet will take 3 s to fall 1 m. A 10 μm droplet will take 300 s, and a 1 μm droplet will take 30,000 s.[11]

Impact of normal breathing, coughing, and sneezing

Droplets are exhaled when we breathe, speak, laugh, cough, or sneeze and these are in the inhalable range for humans.[2] Ordinary speech aerosolizes significant quantities of respiratory particles. In fact, long ago, it was established that ordinary breathing and speech both emit large quantities of aerosol particles.[17,18]

These expiratory particles are typically about 1 μm in diameter, and thus invisible to the naked eye; most people unfamiliar with aerosols are completely unaware that they exist. The particles are sufficiently large, however, to carry viruses such as SARS-CoV-2, and they are also in the correct size range to be readily inhaled deep into the respiratory tract of a susceptible individual.[19]

Experimental work by Morawska *et al*.[20] indicated that vocalization emits up to an order of magnitude more aerosol particles than breathing, and recent work by Asadi *et al*.[21] established that the louder one speaks, the more aerosol particles are produced. Asadi *et al*. further established that, for unclear reasons, certain individuals are "speech superemitters" who emit an order of magnitude more aerosol particles than average, about 10 particles/s. A 10-min conversation with an infected, asymptomatic superemitter talking in a normal volume thus would yield an invisible "cloud" of approximately 6000 aerosol particles that could potentially be inhaled by the susceptible conversational partner or others in close proximity.

As general estimates, particles produced by normal breathing have a velocity of approximately 1 m/s, talking 5 m/s, coughing 10 m/s, and sneezing 20–50 m/s.[22]

Speech is potentially of much greater concern than breathing for two reasons: the particles on average are larger, and thus could potentially carry a larger number of pathogens, and

Table 1: Mask types and filtration effectiveness

Mask type	Standards	Filtration effectiveness		
Single-use face mask (single/two layered)	china	3.o μm ≥95%		
Surgical Mask	China (YY 0469)	3.0 μm: ≥ 95%, 0.1 μm: ≥ 30%		
	USA (ASTM F2100)	Level 1	Level 2	Level 3
		3.0 μm ≥95% 0.1 μm ≥95%	3.0 μm ≥98% 0.1 μm ≥98%	3.0 μm ≥98% 0.1 μm ≥98%
	EUROPE	Type 1	Type 2	Type 3
		3.0 μm ≥95%	3.0 μm ≥98%	3.0 μm ≥98%
Respirator Mask	USA: NIOSH (42 CFR 84) CHINA: GB2626	N95/KN 95	N99/KN99	N100/KN100
		0.3 μm ≥95%	0.3 μm ≥95%	0.3 μm ≥99.97%
	EUROPE: EN 149:2001	FFP1 0.3 μm ≥80%	FFP2 0.3 μm ≥94%	FFP3 0.3 μm 99%

much greater quantities of particles are emitted compared to breathing, thus increasing the odds of infecting nearby susceptible individuals.[21]

Understanding the importance of face mask

Now that we know that the primary route of transmission of SARS-CoV-2 is likely via respiratory droplets and contact. Reducing disease progression will need two interventions: first, reduce transmission from infected individual and second, physical distancing. Universal use of facial mask has shown to be most effective in both clinical and laboratory settings at reducing the spread of infection.[23,24] Masks may also be beneficial by acting as a reminder for wearers to avoid touching their face. Table 1 shows the various types of mask and their effectiveness.

Surgical masks are loose fit devices worn to reduce the transfer of potentially infectious bodily fluids between individuals. These are designed to prevent droplets from an infectious patient from coming in contact with the mucous membranes in the nose and mouth of the person wearing the mask. It must be noted that they are not designed to filter small airborne infectious particles.

Respirators are "medical devices designed to protect the wearer from airborne infectious aerosols." Air-purifying respirators are further classified by the efficiency at which they remove particles, oil resistance, and that are oil proof as in Table 2.

Given the shortages of medical masks, for now, simple cloth masks seem to be a practical solution for use by general population. This has been supported by the United States and European Centres for Disease Control.[23]

Cloth masks work in two ways, as a physical barrier and as electrostatic filters. Electrostatic interactions are commonly observed in various natural and synthetic fabrics.[25] Konda *et al.* studied the filtration efficiencies of various fabrics and found the efficiency improved when multiple layers were used and more specifically with a combination of different fabrics.[24] Filtration efficiencies of the hybrids (such as cotton–silk, cotton–chiffon, cotton–flannel) were >80% (for particles <300 nm) and >90% (for particles >300 nm).

Cotton, natural silk, and chiffon can provide good protection, typically above 50% in the entire 10 nm to 6.0 μm range, provided they have a tight weave. Higher threads per inch cotton with tighter weaves resulted in better filtration efficiencies.[24]

Table 2: Respirators letter and number ratings

Respirator rating letters		Respirator rating number class	
N	Not oil resistant	95	Removes 95% of all particles that are 0.3% μm in diameter
R	Resistant to oil	99	Removes 99% of all particles that are 0.3% μm in diameter
P	Oil Proof	100	Removes 99.97% of all particles that are 0.3% μm in diameter

Materials such as silk and chiffon are particularly effective (considering their sheerness) at excluding particles in the nanoscale regime (<~100 nm), likely due to electrostatic effects[25] that result in charge transfer with nanoscale aerosol particles. Thus, hybrid combinations of cloths such as high threads-per-inch cotton along with silk, chiffon, or flannel can provide broad filtration coverage across both the nanoscale (<300 nm) and micron scale (300 nm to 6 μm) range, likely due to the combined effects of electrostatic and physical filtering.[24]

Increasing the number of layers improves the performance and combining layers to form hybrid masks, leveraging mechanical and electrostatic filtering may be an effective approach for universal use by everyone.

It is critically important that cloth mask designs also take into account the quality of this "fit" to minimize leakage of air between the mask and the contours of the face, while still allowing the exhaled air to be vented effectively.

Finally, it is important to note that openings and gaps (such as those between the mask edge and the facial contours) can degrade the performance. There is evidence that leakages around the mask area can degrade efficiencies by ~50% or more, pointing out the importance of "fit."[24]

To conclude, with a barrier at the source of infection like a face mask in respiratory diseases is an established strategy. This is especially true for the current pandemic where a large number of the population is not only asymptomatic but also unaware of their own being infected. Social distancing and lockdown for sure are potent tools in preventing the spread of the infection, but extreme form of both might not be acceptable for a prolonged time. The universal use of face mask can be an effective tool in slowing and containing the infection. In view of shortage of N95 respirators and surgical masks, a simple layered hybrid cloth mask is an economical and sustainable alternative for the general community so that surgical masks and N95 respirators can be spared for health care workers.

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Conflicts of interest

There are no conflicts of interest.

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